

THE LARVAE OF *CICINDELA THEATINA* (COLEOPTERA: CICINDELIDAE), A REGIONAL NORTH AMERICAN SAND DUNE ENDEMIC¹

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ABSTRACT: The three instars of the Great Sand Dunes tiger beetle, *Cicindela theatina*, are described for the first time from larvae collected at the Great Sand Dunes National Park and Preserve, Colorado. The larvae of *C. theatina* appear similar to those of *C. hirticollis* and *C. limbata*, both members of the North American *repanda* group, to which *C. theatina* belongs.

Approximately 112 species of tiger beetles among four genera are known from North America (Pearson et al. 1997; Morgan et al. 2000). Taxonomically, tiger beetle adults are relatively well-known; however larvae are described for only approximately 57% of the over 100 species known from North America (Valenti 1996; Knisley and Pearson 1984). These include 55 species of *Cicindela*, five species of *Omus*, two *Megacephala* and two *Amblycheila*. The available larval descriptions may or may not be inclusive of all three larval stages while others have only partial descriptions (Valenti 1996). One species in each of the four North American genera was described by G. Horn (1878). Following these descriptions, Shelford (1908) gave concise descriptions of 12 species using habitat, form of burrow, size and color of head and prothorax, and the number and arrangement of dorsocephalic setae as well as distribution of setae on the prothorax as key characteristics. Subsequently, Hamilton (1925) standardized the morphological terminology using *C. limbalis* Klug as the example species reasoning that it was one of the larger and more cosmopolitan species of *Cicindela* in North America. Here he meticulously described the 3rd instars of 30 North American species, including those previously described by Shelford, and presented a larval key using setae on the head and thorax, pronotum and abdomen, as well as color of the head and pronotum as key morphological characters. He also used proportional measurements of one structure to another, i.e., length to the width of the frons, diameter of stemma II to the distance between stemmata I and II, the proportional lengths of the antennal segments, and the length and width of the pronotum as key characteristics.

Cicindela theatina Rotger is placed in the subgenus *Cicindela*, and included in the "western clade" of the North American *repanda* group, or more broadly within the Palearctic *maritima* group (Freitag 1965; Rumpff 1967; Freitag 1972; Morgan et al. 2000). Nearctic species included in the *maritima* group are *C. limbata* Say, *C. bellissima* Leng, *C. columbica* Hatch, *C. arenicola* Rumpff, *C.*

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hirticollis Say, *C. repanda* Dejean, *C. depressula* Casey, *C. oregona* LeConte, and *C. duodecimguttata* Dejean (Freitag 1965; Rumpff 1967), and most recently *C. albissima* Rumpff (Rumpff 1967; Morgan et al. 2000). Analysis of mtDNA data resulted in the elevation of the former *C. limbata albissima* subspecies to species status *C. albissima*, as the findings show that *C. albissima* is only distantly related to other *C. limbata* s.s. (Morgan et al. 2000). Among these 10 remaining species, full or partial larval descriptions are available for all except *C. columbica* and *C. albissima* (Table 1).

Cicindela theatina is an endemic species restricted to shifting sand habitats with sparse vegetation in and around the Great Sand Dunes National Park and Preserve (GRSA), Saguache and Alamosa counties, Colorado (Acorn 1992; Kippenhan 1994). Its first documented observation was by Rotger in 1942, and later described as a new species by Rotger (1944). The preferred habitat of the adults is areas of sparsely vegetated dunes or dune islands with shifting sands of approximately 10% coarse sand, 40% medium sand, 47% fine sand and 3% very fine sand (soil descriptions from Pannell et al. (1973) and Yenter (1984)). The larval burrows of this species are most commonly found in congruent adult habitat, situated on northern aspects of the crests of dune blowouts where the vegetation is more apparent. Likewise, larval burrows are also encountered at the bases of dune blowouts near more apparent vegetation. Rarely were burrows encountered directly in the bare sand or blowouts themselves; however, presence of burrows in such barren habitats are subject to the effects of sand saltation during windy intervals which may consequently obscure the burrows (Pineda 2002).

The objective of this study is to describe the three larval instars of *C. theatina* using the format proposed by Hamilton (1925). Characters of each instar are illustrated and described.

Table 1. Described cicindelid larvae of the Palearctic *maritima* group. Adapted from Valenti (1996).

Species	Site of Collection/ Instar Described	Year described
<i>C. bellissima</i> Leng	Field, Third instar	Leffler (1979) (no measurements)
<i>C. depressula</i> Casey	Field, Third instar	Leffler (1979) (no measurements)
<i>C. duodecimguttata</i> Dejean	Laboratory reared	Hamilton (1925)
<i>C. hirticollis</i> Say	Field, Third instar	Hamilton (1925)
<i>C. limbata</i> Say	Field, Third instar	Hamilton (1925)
<i>C. oregona</i> LeConte	Field, Third instar	Hamilton (1925)
<i>C. oregona</i> LeConte	Field, Third instar	Leffler (1979) (no measurements)
<i>C. repanda</i> Dejean	Field, Third instar	Leffler (1979) (no measurements)
<i>C. arenicola</i> Rumpff	Field, Third instar	Rumpff (1967) (brief desc. of third instar)

MATERIALS AND METHODS

A population of *C. theatina* was observed at Indian Spring Natural Area (ISNA) in June of 1999, just west of the GRSA boundary in Saguache County. The ISNA is situated in a geomorphological area of the Great Sand Dunes depositional system known as the sand sheet, characterized by undulating transverse dunes that may be as high as 200 m (656 ft) in height (Andrews 1981). Vegetation typically consists of *Chrysothamnus nauseosus* (Pallus ex Pursh) Britt / *Oryzopsis hymenoides* (Roemer and J.A. Schultes) Ricker ex Piper (rabbitbrush/ Indian rice grass) communities and *Redfieldia flexuosa* (Pursh) Rydb. (blowout grass) or *Psoralidium lanceolatum* (scurf pea) (Thurb.) Vasey in the shifting sand areas. A spring and wetland are situated within the site, dominated by *Salix exigua* Nutt. (coyote willow), *Juncus balticus* Willd. (baltic rush) and *Scirpus pungens* Vahl. (bulrush) within the wetland. Adults, 1st, and 3rd instar larvae were collected at a blowout just south of the wetland. The larvae were preserved on-site in 80% ethanol solution. On 22 June 1999, field-collected adult males and females were placed in a 10 in x 20 in x 12 in glass terrarium filled with sand from the collection site. Sand depth ranged from three to 10 centimeters (sloped) to provide some relief within the terrarium. Prior to placement of sand and tiger beetles, two pieces of 1.25 cm polyvinyl chloride (PVC) pipe were sized to fit the bottom and side of the terrarium. That which was sized for the bottom (48.30 cm) was drilled with a small bit at three-centimeter intervals, capped at one end, and connected at the opposite end with an elbow joint to a 22.80 cm piece of PVC pipe (no holes) at a 90° angle. The apparatus was subsequently fit into the terrarium. This was designed so that the sand could be watered evenly from beneath. The bottom half of a Pyrex Petri dish (9 cm diameter) was placed at the lower corner of the terrarium, in which a sponge was placed and dampened with water to provide hydration for adults. The laboratory temperature ranged from 22 - 25°C (71.6 - 77.0° F). Adults were fed a variety of invertebrates, including immature *Cylisticus convexus* DeGeer (Isopoda; pillbugs), early instar *Acheta domesticus* L. (Orthoptera: Gryllidae; pinhead crickets), *Galleria mellonella* L. larvae (Lepidoptera: Pyralidae; waxworms), and oatmeal (introduced for the crickets).

On 26 July 1999, four larval burrows were observed within the terrarium. The sand from the terrarium was subsequently sifted, and three 2nd instar larvae were selected from 12 found to be present. These larvae were preserved by boiling in water for five minutes, and then transferred to a vial containing 80% ethanol solution. The remaining larvae were transferred to laboratory habitats for observation.

Material examined: Two 1st instar larvae and three 3rd instar larvae collected from Colorado, Saguache County, ISNA, west of GRSA, 20 June 1999; three 2nd instar larvae, reared from adult population, Colorado, Saguache County, ISNA west of GRSA, preserved 26 July 1999. Specimens are depos-

ited in the collection of the C.P. Gillette Museum of Arthropod Diversity, Colorado State University.

RESULTS

First instar larvae

Color: Head and labrum dark brown with bronze and green reflections; antennae dark brown; mandibles yellow-brown basally with apices and retinaculum dark brown; labium brown; dorsocephalic and pronotal setae white; remaining setae yellow-brown; pronotum brown to dark brown with cupreous and teal-green reflections; cephalolateral angles yellow-brown; mesonotum brown; metanotum brown but lighter than mesonotum; abdominal sclerites light brown.

Head: Dorsal setae medium in length; diameter of stemmata I and II equal or nearly equal; distance between stemmata equal to diameter; U-shaped ridge on caudal portion of frons lacking setae; distal antennal segment shortest in length; penultimate segment next shortest; however, proximal and penultimate segments nearly equal in length; second segment longest in length; proximal antennal segment lacking setae; second segment with one large and one small setae; penultimate with one small, one medium and one large setae; distal with 3 setae; maxilla with one mesal seta on galea; maxillary palpus 3-segmented; palpifer with 3 setae; penultimate segment of palpus with 2 stout setae; proximal segment with no setae; distal with one ventral seta; ligula with 2 small transverse setae.

Thorax: Pronotum broad and V-shaped (Fig. 2), with lateral margins very slightly keeled; 7 primary setae present, secondary setae mostly absent.

Abdomen: Sclerotized areas are easily distinguished; eusternum of ninth segment with 2 groups of 2 caudal setae each; pygopod with 10 setae; median hook of fifth segment with 1 seta; inner hooks with 1 seta each; spine of inner hook nearly 2/3 length of entire hook.

Measurements (mean only; 2 specimens examined): Total length 5.6 mm; width at third abdominal segment 0.24 mm; diameter of stemmata I and II 0.13 mm; distance between stemmata I and II 0.13 mm; length of fronto-clypeal-labral area 0.74 mm; width of pronotum 1.38 mm; length of pronotum 0.89 mm; mandible length 0.99 mm; length of proximal antennal segment 0.13 mm; second 0.21 mm; penultimate 0.14 mm, distal 0.12 mm.

Second instar larvae

Color: Head and labrum brown to dark brown with cupreous and green or teal-green reflections; antennae brown; mandibles yellow-brown basally with apices and retinaculum dark brown; maxillae opaque yellow basally, clear-brown apically; labium brown; dorsocephalic and pronotal setae white; remaining setae yellow-brown; pronotum brown with bronze and teal reflections; cephalolateral angles brown; mesonotum light brown anteriorly, cloudy brown posteriorly; metanotum same as posterior mesonotum; abdominal sclerites light brown.

Head: Setae on dorsum medium in length, diameter of stemmata I and II equal; distance between stemmata equal or nearly equal to diameter; U-shaped ridge on caudal portion of frons lacking setae; second antennal segment longest, and distals nearly equal in length to each other and shorter than the proximal; proximal antennal segment lacking setae; second with 2 setae; penultimate with 2 medium and 1 short setae; distal with 2 long setae; maxilla with one mesal seta; maxillary palpus three-segmented; palpifer with 2 setae; penultimate segment of palpus with 2 setae; proximal and distal lack setae; distal segment of labial palpus with one seta, proximal segment with 2 spurs, no seta on mesal side of spurs, none on lateral side; ligula with 4 transverse setae.

Thorax: Pronotum broad and V-shaped (Fig. 3); lateral angles very slightly keeled; 7 primary setae; very few secondary setae, 2 pair or less.

Abdomen: Sclerotized areas easily distinguished; eusternum of ninth segment with 2 groups of 3 caudal setae each, pygopod with 12 setae; median hooks of fifth segment with one setae; inner hooks with 2 setae; spine of inner hook approximately 3/5 length of entire hook.

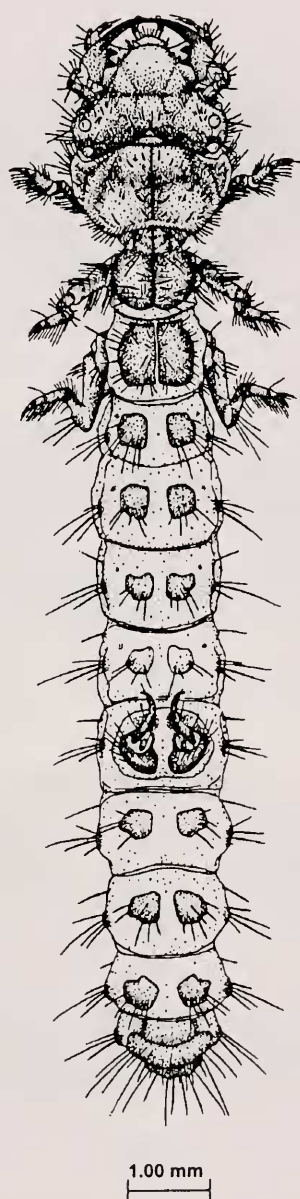


Fig. 1. Third instar larva of *C. theatina*, dorsal view.

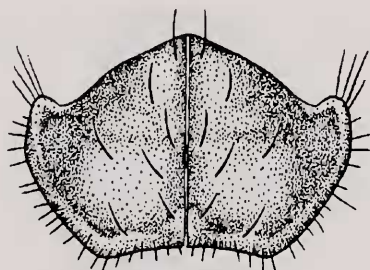


Fig. 2. First instar *C. theatina*, pronotum, dorsal view.

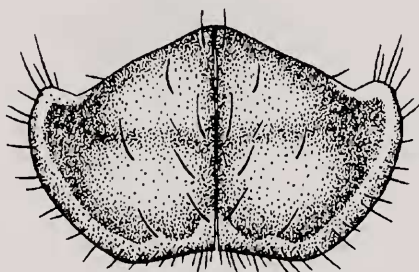


Fig. 3. Second instar *C. theatina*, pronotum, dorsal view.

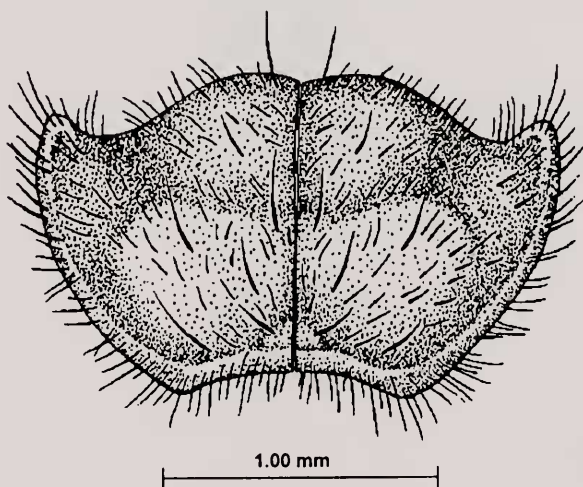


Fig. 4. Third instar *C. theatina*, pronotum, dorsal view.

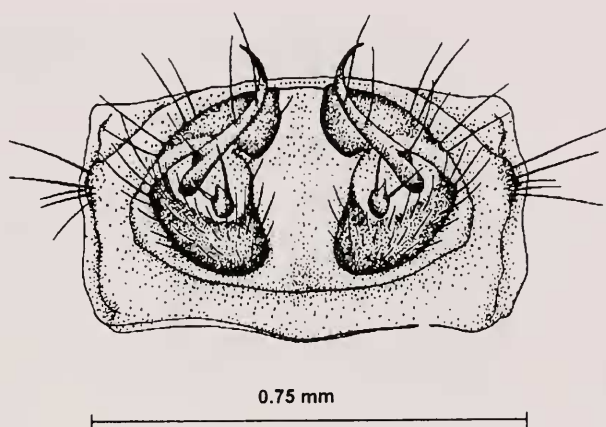


Fig. 5. Third instar *C. theatina*, fifth abdominal segment.

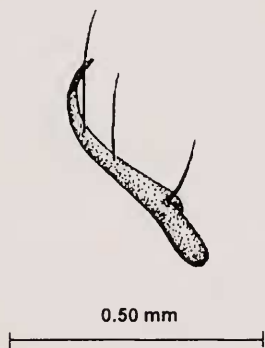


Fig. 6. Third instar *C. theatina*, right median hook, fifth abdominal segment.



Fig. 7. Third instar *C. theatina*, right inner hook, fifth abdominal segment.

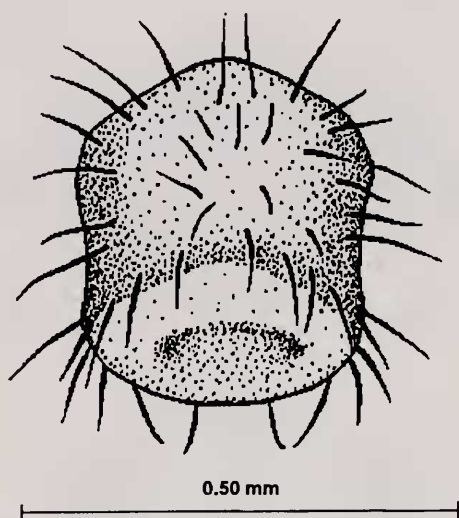


Fig. 8. Third instar *C. theatina*, pygopod, dorsal view.

Measurements (mean only; 3 specimens examined): Total length 8.01 mm; width at third segment 0.94 mm; diameter of stemmata I and II 0.15 mm; distance between stemmata 0.14 mm; length of fronto-clypeal-labral area 1.10 mm; width of pronotum 1.39 mm; length of pronotum 0.96 mm; mandible length 0.93 mm; length of proximal antennal segment 0.20 mm; second, 0.21 mm; penultimate 0.13 mm; distal 0.13 mm.

Third instar larvae

(Fig. 1)

Color: Head and labrum dark brown with bronze and green reflections; antennae dark brown; mandibles amber-brown basally with dark brown to nearly black apices and retinaculum; maxillae amber-brown to dark brown; labium dark brown, dorsocephalic and pronotal setae white; remaining setae yellow-brown; pronotum brown to dark brown with cupreous and teal-green reflections; cephalolateral angles amber-brown; mesonotum brown, metanotum brown but lighter than mesonotum, abdominal sclerites light brown.

Head: Dorsal setae medium to long in length; diameter of stemmata I and II equal; distance between stemmata equal or nearly equal to diameter; U-shaped ridge on caudal portion of frons with 3-4 setae; distal segment shortest in length, proximal and penultimate both shorter than second segment; proximal antennae segment with 7 setae; second with 9-10 setae; penultimate with 1 or 2 setae, distal with 3 setae; maxilla with 2 mesal setae; palpifer with 3 setae; penultimate segment of palpus with 2 setae; proximal and distal lacking setae; distal segment of labial palpus with one seta; proximal segment with 2 spurs and 3 setae; ligula with 4 small transverse setae.

Thorax: Pronotum broad and V-shaped (Fig. 4); lateral angles nearly planar; 7 primary setae; secondary setae numerous, > 30 pairs.

Abdomen: Sclerotized areas easily distinguished; eusternum of ninth segment with 2 groups of 5 caudal setae each; pygopod with 19 setae (Fig. 8); median hook (Fig. 6) of fifth segment (Fig. 5) with 2 or 3 setae, inner hooks with 2 setae each (Fig. 7); spine of inner hook between 1/2 to 2/3 length of entire hook.

Measurements (mean only, 3 specimens examined): Total length 1.23 cm; width at third segment 1.17 mm; diameter of stemmata I and II 0.18 mm; distance between stemmata 0.19 mm; length of fronto-clypeal-labral area 0.99 mm; width of pronotum 2.06 mm; length of pronotum 1.36 mm; mandible length 1.33 mm; length of proximal antennal segment 0.26 mm; second, 0.30 mm; penultimate 0.16 mm; distal 0.14 mm.

DISCUSSION

Using Hamilton's (1925) key, the 3rd instar larvae of *C. theatina* evidently key to couplet 31. At couplet 31, if one only uses the character "median hooks with less than four setae", and disregards other mentioned characters, the larvae can then be keyed to couplet 33, which includes both *C. hirticollis* and *C. limbata*, both of which are included in the Nearctic *repanda* group to which *C. theatina* belongs. *Cicindela theatina* differs at couplet 31 in having the caudal margin of the ninth abdominal sternum bearing two groups of 5 caudal setae each, and the pronotum having secondary setae less than 100 in number. At couplet 33, *C. theatina* differs from *C. limbata* in having the proximal segment of the antennae bearing 7 setae, while *C. limbata* bears 12 to 13.

For pronotal primary setae, Hamilton (1925) prepared a numbering system for these, as many species possess 7 per side. Among the three instars of *C. theatina*, all bear the equivalent number of pronotal setae, which is numbered at 7. The dorsocephalic and pronotal setae are consistently white in color among all instars. Secondary pronotal setae were found to be present only in the 2nd and 3rd instars, and varied from 1 or 2 pairs for the second instar, to > 30 pairs for the third instar larvae.

Eleven species of *Cicindela* are known to occupy various habitats within the GRSA ecosystem (Pineda 2002). In habitats within this ecosystem where *C. theatina* occurs, other larvae and adults of tiger beetles, depending on adjacent habitat types, occur. For example, in *C. theatina* habitats adjacent to grassy or grass and shrub communities (between 34.1 and 67.6% vegetative cover), *C. f. formosa* Say can be common, with the larvae often found in areas of higher vegetative cover than that noted for adult *C. theatina* (between 0.20 and 15.04 percent) (Pineda 2002). In *C. theatina* habitats occurring near ephemeral creeks, the larval burrows as well as the adults of *C. hirticollis shelfordi* Graves may be found in abundant and concentrated numbers near the water's edge. Likewise, *C. theatina* habitats that are adjacent to wetlands or damp playas will also harbor profuse numbers of *C. r. repanda* Dejean adults and larvae. Rarely has *C. tranquebarica* Herbst or *C. punctulata* Olivier been found sympatrically with *C. theatina*.

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